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MATERIALS METHOD N.Y. 5.13

NEW YORK STATE

DEPARTMENT OF TRANSPORTATION

MATERIALS BUREAU

MARSHALL MIX DESIGN

PRELIMINARY

(NOT OFFICIAL)

ISSUED FOR DEPARTMENT
REVIEW AND COMMENTS

April 23, 1981

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I. SCOPE

This Materials Method describes the procedures, responsibilities and requirements for the preparation, submission and approval of bituminous concrete job mix formula requiring Marshall Mix Design. The method outlines a complete procedure for the analysis and design of top course mixtures and eliminates as many variables as possible to result in a precise and uniform submission.

II. GENERAL

The primary purpose of the Marshall Design is to develop mixes that are capable of achieving good Marshall properties, while at the same time optimize the use of asphalt cement. Optimizing asphalt cement does not necessarily mean using less asphalt in a given mix, but rather using the asphalt cement content that will result in a mixture having desirable properties.

The Marshall Method is a good tool to aid the Materials Engineer in predicting the pavement serviceability of a bituminous mixture. It also gives the Materials Engineer data to determine what effect an asphalt cement content adjustment will have on pavement performance. When pavement experiences exist, using the same or similar materials and gradation, they should be considered in conjunction with the Marshall data in determining the actual production asphalt cement content to be used.

The Marshall Design is basically a one-time requirement. A complete design is required to be prepared and submitted by the Producer. This design results in an optimum asphalt cement content, and establishes Marshall properties at varied asphalt cement contents other than optimum. Subsequent annual job mix formula, utilizing the same source materials and gradation, do not require additional Marshall testing.

The Materials Engineer, after receiving the producers design submission, reviews all data and verifies Marshall properties at selected asphalt cement contents. After this review and testing the Regional Director either rejects the submitted design due to inaccuracy, or recommends approval to the Deputy Chief Engineer, Technical Services.

III. INFORMATION SOURCES

The following listing makes reference to the various sources of information, in addition to this Method, that must be consulted in preparing a Marshall Mix Design.

SOURCE	INFORMATION
Specifications (including all addenda and project proposal)	Mix Criteria
Approved Aggregate Source Listing	Aggregate Specific Gravities, current source and test numbers
NYSDOT Materials Method 5	Hot Bin Aggregate Sampling and Sieving Procedures
NYSDOT Materials Method 5.12	Aggregate Sampling Procedures for Drum Mix Plants
Asphalt Cement and Mineral Filler Supplier	Asphalt Cement and Mineral Filler Specific Gravities
Regional Office	Hot Bin History Data, and Approved Aggregate Source Listing
ASTM Test Methods D1559, D2041, and D2726	Supplement the procedrues outlined in this method where referenced

IV RESPONSIBILITIES

A. Producer

The Producer is responsible for furnishing the Department a Marshall Design for the specified mixes in accordance with the procedures outlined in this method. The resultant mix properties must meet the specified mix criteria.

A complete Marshall Design must be submitted for each job mix formula utilizing different aggregate sources. Additionally, if more than one plant utilizes the same materials, a separate design is required for each plant. The Regional Director or his represenatative may waive the requirement for separate mix designs, provided that the effect of the plants screening mechanism and/or changes in material will have little effect on the resultant Marshall properties. In this case the Producer is required to monitor plant mix material and determine Marshall stability, flow, air voids, voids in the mineral aggregate and voids in the mineral aggregate filled with asphalt cement. This monitoring requirement shall continue until the Regional Director or his represenatative is assured that the resultant mix performs in a manner as that originally designed.

Producer's responsibilty includes:

1. Analysis of plant aggregate gradation - This involves the gathering of hot bin data for a given mix, and developing an average gradation that the plant is capable of producing. Department records may be used by the Producer in developing this history.

2. Obtaining Hot Bin or composite aggregate samples - The producer shall obtain representative Hot Bin or composite aggregate samples in accordance with instructions outlined in Materials Method 5. A sufficient quantity of samples shall be obtained for the producer to prepare a minimum of 25 specimens, and a sufficient quantity for the Department to prepare a minimum of 15 specimens. The producer shall notify the Regional Director, or his representative as to the time and date of sampling.

3. Specimen Formulation - The Producer shall determine batch weights to prepare Marshall specimens that result in a formulation of aggregate components identical to that produced at the plant. Procedures outlined in this method must be followed.

4. Specimen Batching and Compaction - The Producer is required to prepare a minimum of five specimens at each selected asphalt content, three (3) compacted and two (2) uncompaced, in accordance with procedures outlined in this method. A minimum of five asphalt contents, at intervals of either 0.4 or 0.5 percent, must be evaluated. The aggregate gradation and a minimum of three of the selected asphalt contents must fall within the specified General Limits listed in Table 401-1 of the Standard Specifications.

5. Testing of Marshall Specimens - The Producer is required to test a minimum of twenty-five (25) Marshall specimens. Fifteen (15) compacted specimens shall be tested to determine Bulk Specific Gravity, Stability and Flow. Ten (10) uncompacted specimens shall be tested to determine the Maximum Theoretical Specific Gravity. These tests shall be conducted in accordance with procedures outlined in this Method.

6. Analysis of Marshall Test Data - The Producer shall analyze his resultant data, in accordance with procedures outlined in this Method to determine the following properties.

   a. Unit Weight
   b. Air Voids
   c. Voids in the Mineral Aggregate (V.M.A.)
   d. V.M.A. filled with asphalt
   e. Corrected Stability
   f. Optimum Asphalt Content
   g. Mix Properties at Optimum Asphalt Content

7. Data Documentation - The Producer shall document his resultant test data on Department forms. Forms required are as follows:

   BR-88 Marshall Gradation Analysis Worksheet
   BR-76 Maximum Specific Gravity of Bituminous Paving Mixtures
   BR-77 Worksheet for Analysis of Compacted Paving Mixture
   BR-78 Marshall Test Property Curves
   BR-79 Bituminous Concrete Testing Report - Computation of Marshall Mix Properties

8. Marshall Design Submission - The Producer shall submit to the Regional Director the completed Mix Design. Included in the Mix Design submission shall be:

   - the above listed forms completed in a neat manner
   - the corresponding job mix formula listing the materials and gradation evaluated.
   - the individual hot bin (or composite gradation for Drum Mix plants) and extraction test data used to generate the gradation listed on the BR-88.

B. Department

The following outlines the minimum requirements performed by the Department at the Region for reviewing a Marshall Mix Design.

1. Review submitted Marshall gradation to determine if it is representative of actual plant production.

2. Check computations for the submitted Marshall Bulk and Rice theoretical density data. Also check for excessive variation at a given asphalt content. This indicates the lack of good lab technique. Excessive variation is defined as follows:

what is this based on

	Within Lab	Lab to Lab (Verification test)
Bulk Specific Gravity	0.02	0.02
Rice Theoretical Specific Gravity	0.011	0.019

3. Check plotted Marshall curves for proper plotting and curve fitting. Curves should have reasonably consistent patterns. Trends generally noted are explained in Chapter V Section F of this manual "Curve Trends and Relations".

4. Check curve interpretation and calculations applied to determine optimum asphalt content. Next, check to determine if Marshall Specification criteria are met at the optimum and/or selected asphalt cement content.

5. Laboratory verification of mix designs is desirable but not required for approval. However, if a questionable design is submitted, it is strongly recommended that verification be performed. The purpose of verification is to check technique used to complete the submitted design. Excessive differences in Marshall properties determined in verification test will result in a mix design rejection. These differences are listed above under Paragraph 2.

6. Review Job Mix Formula for accuracy and completeness.

7. The Region, after completing its review of the submitted mix design and any other pertinent information, will select a production asphalt cement content.

Upon a favorable Regional recommendation, indicated by the Regional Director's signature, the Job Mix Formula plus all pertient Marshall Design data are sent to the Materials Bureau for final review and approval. Once approved, four (4) copies are retuned to the Region for distribution: Region Office, Region Lab, Plant Inspector, and Producer.

V. MARSHALL MIX DESIGN PROCEDURE

This section outlines specific procedures to be followed by both the producer and region laboratory when evaluating a bituminous plant mix for Marshall properties. This section outlines the complete procedure for the testing and analysis to establish Marshall Mix Properties and eliminates as many variables as possible to result in precise and uniform testing.

A. Analysis of Plant Aggregate Gradation

The analysis of aggregate gradations and the combining of aggregates to obtain the desired gradation are important steps in the Marshall Design. The Producer must analyze and select an aggregate gradation that conforms to the Department specified General Limits listed in Table 401 -1 of the Standard Specifications and yields a mix that meets the specified Marshall criteria.

This section outlines the method of analyzing aggregates for the Marshall Mix Design. There are two types of plants which require different analysis methods. They are batch plants which incorporate their own aggregate screening system, and drum mix plants, whose control of aggregate gradation is based on the stockpiles. Each of these systems will be outlined separately as to Department requirements for Marshall Design aggregate analysis and sampling.

Also, when analyzing aggregate gradation for either plant type two distict situations may exist. Plants which have established historical gradation data can result in a Full Design approval. Plants whose aggregate gradation has no historical data can only result in a Tentative Design approval until the historical data is developed. Examples of tentative approval are new plants or plants whos mixes require a major gradation adjustment to obtain acceptable Marshall properties.

1. Batch Plants

a. Full approval

The following describes the procedure to be followed by the Producer for the formulation of a trial gradation for those plants having historical aggregate data. Department form BR-88 "Marshall Gradation Analysis Worksheet" shall be used to docmument this data.

(1). Obtain a hot bin history of the material that has been produced in the past. This should consist of a minimum of ten (10) passing hot bins. From the hot bin history, a tabulation of the individual stone sizes should be made (i.e., No. 1, No. 1A, Screenings or Blended Fines). When aggregate blends occur the approximate cold feed blend percentages should be documented. From these tabulations determine the average gradation of each stone size that the plant produces. Careful attention must be given to insure that the hot bin gradations and aggregate samples are representative.

NOTE: Plants equipped to re-add all of its fines from the dust collection system or varying amounts of its dust collector fines should be carefully analyzed when evaluating the hot bin history. This aspect should be held constant for those hot bins averaged and when obtaining hot bin aggregate samples for the preparation of Marshall specimens.

The extraction test is useful for comparison purposes to determine if the minus #80 and minus #200 are within the General Limit specification. However, the extraction test

gradation cannot be used to prepare the Marshall specimens, since in essence this is a washed sieve analysis and washed aggregates will not be batched.

(2). When the average gradation is determined for each stone size from hot bin history, a combined gradation is prepared by applying the percent batch to the average hot bin gradation for each bin. The averaged individual percent retained for each stone size must be calculated in order to determine the batching weights for the Marshall specimens. These details are further explained in Section V-B Marshall Specimen Formulation. See Figure V-A-1 for typical analysis documentation.

The "percent batch" that the producer has been utilizing should be kept constant since a change may vary the gradation of the stone sizes due to the plant screening mechanism. At times it may be advantageous to fine tune the percent batch provided the change does not result in a change in cold feed rates to maintain bin levels.

b. Tentative Approval

Those plants not having a history of aggregate gradations may be approved on a tentative basis in order to develop a thorough plant history for the materials and/or gradation selected to be used.

This tentative approval requires that the producer establish an aggregate gradation and asphalt content within the general limits and determines, with supporting Marshall data, that specified Marshall properties are obtainable. Marshall data at other than the selected asphalt content is not required for tentative approval. The Region will then sample plant mix material batched to the established gradation and asphalt content.

If acceptable Marshall properties are achieved by the Region through testing of the plant mix material, a tentative approval may be given by the Regional Director or his representative.

After sufficient tonnage has been produced to develop a plant gradation history, the producer must prepare a full mix design using hot bin materials as outlined in Section V-A - 1a of this method. The Regional Director will notify the producer as to when, in the opinion of the Department, sufficient gradation history has been developed. The producer has four (4) weeks from that date to submit the completed mix design.

2. <u>Drum Mix Plants</u>

a. Full Approval

The following describes the procedure to be followed by the Producer for the formulation of a trial gradation for those plants having historical aggregate data. Department form BR-88 "Marshall Gradation Analysis Worksheet" shall be used to document this data.

(1). Obtain a composite aggregate history utilizing materials proportioned to represent mixes successfully produced in the past. This should consist of a minimum of ten (10) passing composite samples. From the composite history a tabulation of the average individual sieve

BR-88 (5/80)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION

MATERIALS BUREAU

MARSHALL GRADATION ANALYSIS WORKSHEET

TESTING AGENCY ABC TESTING INC.

TESTED BY J. BUSHEY ON 1/16/81

NO. OF HOT BINS AVERAGED 10

PLANT XYZ BIT. CORP.
SMITHTOWN, NY

REGION 11

ITEM 18403.1711

MIX TYPE 6F

AGGREGATE SOURCES

Course: #1 9-6R 40%
1-9G 60%
#1A 9-6R 100%

Fine: 9-6R 70%
9-9F 30%

Mineral Filler:
NONE

AVERAGE BIN BREAKDOWN

Sieve Sizes	BIN NO. 1		BIN NO. 1A		BIN NO. FINE		MINERAL FILLER	
	%		%		%		%	
	retained	pass	retained	pass	retained	pass	retained	pass
1"	0	100.0						
1/2"	0.1	99.9		100.0				
1/4"	97.2	2.7	8.6	91.4		100.0		
1/8"	2.2	0.5	85.7	5.7	0.2	99.8		
20			5.2	0.5	39.4	60.4		
40					30.0	30.4		
80					14.8	15.6		
200					8.3	7.3		
PAN	0.5		0.5		7.3			
TOTALS	100.0		100.0		100.0			

COMBINED AVERAGE GRADATION

BIN	%	% Passing Sieve							
	BATCH	1"	1/2"	1/4"	1/8"	20	40	80	200
1	22.3	22.3	22.3	0.6	0.1				
1A	35.1	35.1	35.1	32.1	2.0	0.2			
FINE	42.6	42.6	42.6	42.6	42.5	25.7	13.0	6.6	3.1
Min. Filler									
TOTAL	100.0	100.0	100.0	75.3	44.6	25.9	13.0	6.6	3.1
Spec. LIMITS			95/100	65/85	36/65	15/39	8/27	4/16	2/6

COMBINED MARSHALL GRADATION @ 5.0 % BITUMEN

BIN	%	GRAMS	WEIGHT RETAINED (GRAMS)									TOTAL Wgt. Ret.
	BATCH	BATCH	1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	
1	22.3	254.2		0.3	247.0	5.6					1.3	254.2
1A	35.1	400.1			34.4	342.9	20.8				2.0	400.1
FINE	42.6	485.7				1.0	191.3	145.7	71.9	40.3	35.5	485.7
Min. Filler												
TOTAL	100.0	1140.0	1200.0 gr. X 5.0 % Bit. = 60 gr. A. C.									
			1200.0 gr. − 60 gr. A. C. = 1140 gr. Aggregate									

Remarks:

(over)

FIGURE V-A-1

COMBINED MARSHALL GRADATION @ ___. ___% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL												

1200.0 gr. X ________ % Bit. = ________ gr. A. C.
1200.0 gr. − ________ gr. A. C. = ________ gr. Aggregate

COMBINED MARSHALL GRADATION @ ___. ___% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL												

1200.0 gr. X ________ % Bit. = ________ gr. A. C.
1200.0 gr. − ________ gr. A. C. = ________ gr. Aggregate

COMBINED MARSHALL GRADATION @ ___. ___% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL												

1200.0 gr. X ________ % Bit. = ________ gr. A. C.
1200.0 gr. − ________ gr. A. C. = ________ gr. Aggregate

COMBINED MARSHALL GRADATION @ ___. ___% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL												

1200.0 gr. X ________ % Bit. = ________ gr. A. C.
1200.0 gr. − ________ gr. A. C. = ________ gr. Aggregate

Remarks: ________

sizes should be made. The aggregate cold feed blend percentages should be documented and held constant for all those composite samples being averaged.

(2). Extraction test history is also a value for comparison purposes. Extraction results should be used to evaluate the effect of the dust collection system on the 80 and 200 size material in the finished mix.

In the case, where dust collection fines are totally or partially wasted it may be necessary to decrease the amount of 80 and 200 material in the composite samples when preparing Marshall specimens.

NOTE: The extraction test gradation cannot be used for preparing the Marshall specimen, since in essence this is a washed sieve analysis and washed aggregate will not be batched.

(3). After the average percent passing composite gradation is determined from the composite history, the average individual percent retained for each sieve size is calculated to determine the batching weights for the Marshall specimens. The details are further explained in Section V-B Marshall Specimen Formulation.

Plants equipped to add mineral filler must also calculate the passing and retained percentages for the filler by sieve size in order to determine the total composite gradation. Figure V-A-2 shows Department form BR-88, "Marshall Gradation Analysis Worksheet", completed for a typical drum plant utilizing a mineral filler.

b. Tentative Approval

Those plants not having a history of aggregate gradation may be approved on a tentaive basis in order to develop a thorough plant history for the materials and/or gradation selected to be used.

This tentative approval requires that the producer establish an aggregate gradation and asphalt content within the general limits and determines, with supporting Marshall data, that specified Marshall properties are obtainable. Marshall data at other than the selected asphalt content is not required for tentative approval. The Region will then sample plant mix material batched to the established gradation and asphalt content. If acceptable Marshall properties are achieved by the Region through testing of the plant mix material, a tentaive approval may be given by the Regional Director or his representative.

After sufficient tonnage has been produced to develop a plant gradation history, the producer must prepare a full mix design using composite samples as outlined in Section V-A-2a of this method. The Regional Director will notify the producer as to when in the opinion of the Department sufficient gradation history has been developed. The producer has four (4) weeks from that date to submit the completed mix design.

BR-88 (5/80)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION

MATERIALS BUREAU

MARSHALL GRADATION ANALYSIS WORKSHEET

TESTING AGENCY ABC TESTING INC.

TESTED BY J. BUSHEY ON 1/16/81

NO. OF HOT BINS AVERAGED 10 "COMPOSITE SAMPLES"

PLANT XYZ BIT. CORP.
SMITHTOWN, N.Y.

REGION 11

ITEM 18403.1711

MIX TYPE 6F

AGGREGATE SOURCES

Course: #1 9-6R 40%
1-9G 60%
#1A 9-6R 100%

Fine: 9-6R 70%
9-8F 30%

Mineral Filler:
LIME

AVERAGE BIN BREAKDOWN

Sieve Sizes	BIN NO. COMPOSITE % retained	BIN NO. COMPOSITE % pass	BIN NO. % retained	BIN NO. % pass	BIN NO. % retained	BIN NO. % pass	MINERAL FILLER % retained	MINERAL FILLER % pass
1"		100.0						
1/2"	0	100.0						
1/4"	24.7	75.3						
1/8"	30.7	44.6						
20	18.7	25.9						100.0
40	12.7	13.2					0	100.0
80	8.0	5.2					10.0	90.0
200	3.4	1.8					5.0	85.0
PAN	1.8						85.0	
TOTALS	100.0						100.0	

COMBINED AVERAGE GRADATION

BIN	% BATCH	% Passing Sieve 1"	1/2"	1/4"	1/8"	20	40	80	200
COMPOSITE	96.0	96.0	96.0	72.3	42.8	24.9	12.7	5.0	1.7
Min. Filler	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.6	3.4
TOTAL	100.0	100.0	100.0	76.3	46.8	28.9	16.7	8.6	5.1
Spec. LIMITS			95/100	65/85	36/65	15/39	8/27	4/16	2/6

COMBINED MARSHALL GRADATION @ 5.0 % BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
COMPOSITE	96.0	1094.4			270.3	~~336.0~~ 335.9	204.7	139.0	87.6	37.2	19.7	1094.5
Min. Filler	4.0	45.6							4.6	2.3	~~38.8~~ 38.7	45.7
TOTAL		1140.0	1200.0 gr. X 5.0 % Bit. = 60 gr. A. C.									
			1200.0 gr. − 60 gr. A. C. = 1140 gr. Aggregate									

Remarks:

FIGURE V-A-2

B. Marshall Specimen Formulation

The producer shall obtain representative Hot Bin or composite aggregate samples in accordance with instructions outlined in Materials Method 5. A sufficient quantity of samples shall be obtained for the producer to prepare a minimum of 25 specimens, and a sufficient quantity for the Department to prepare a minimum of 15 specimens. Since additional testing is often required, it is recommended that additional aggregate components be obtained when sampling.

Also obtain at least 2 gallons of asphalt cement in approximately 4 to 6 individual containers so that reheating can be avoided.

> NOTE: When sampling the asphalt cement, use the approved sampling valve and drain off at least one gallon from the spout before sampling.

The Region should be notified as to the time of sampling, to insure that representative Hot Bin or compsite samples are obtained.

1. Five Marshall specimens shall be prepared by the Producer for each of the five different asphalt contents used in the mix design. Three Marshall specimens shall be compacted to test for the Marshall Design Criteria and two shall remain uncompacted for use in the Rice Test, ASTM D2041 "Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures".

2. Dry each aggregate component thoroughly to constant weight and sieve each component by the sieve mechanism or equivalent to be used during quality control testing. Experience has shown that different mechanical sieve mechanisms have varying maximum sample sizes. To prevent sieve overloading and resultant underscreening follow the requirements for aggregate sampling and testing outlined in NY Materials Method 5.

3. Design Specimen Formulation

   a. All specimens must be reconstituted per aggregate component (Bin) and per sieve size and mixed individually (see Figure V-A-1, Combined Marshall Gradation). Drum mix plants will be reconstituted as one aggregate componet (Bin), excepting the addition of a mineral filler (See Figure V-A-2, Combined Marshall Gradation).

   b. Set the total weight of each mix specimen equal to 1200.0 grams.

   c. Determine the weight of the specimen's asphalt cement content by multiplying the predetermined asphalt cement content percentage by the total weight of the specimen (i.e., at 6.0% A.C., then 0.06x1200.0 = 72.0 grams of A.C.).

   d. Determine total weight of aggregate as follows: total aggregate weight = (1200.0 - A.C. weight in grams).

   e. Determine the total weight (grams batched) of each individual aggregate component in the specimen by multiplying its predetermined batch percentage by the total weight of the aggregate in the specimen.

COMBINED MARSHALL GRADATION @____. ____% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL			1200.0 gr. X ______ % Bit. = ______ gr. A. C.									
			1200.0 gr. − ______ gr. A. C. = ______ gr. Aggregate									

COMBINED MARSHALL GRADATION @____. ____% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL			1200.0 gr. X ______ % Bit. = ______ gr. A. C.									
			1200.0 gr. − ______ gr. A. C. = ______ gr. Aggregate									

COMBINED MARSHALL GRADATION @____. ____% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL			1200.0 gr. X ______ % Bit. = ______ gr. A. C.									
			1200.0 gr. − ______ gr. A. C. = ______ gr. Aggregate									

COMBINED MARSHALL GRADATION @____. ____% BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
Min. Filler												
TOTAL			1200.0 gr. X ______ % Bit. = ______ gr. A. C.									
			1200.0 gr. − ______ gr. A. C. = ______ gr. Aggregate									

Remarks ____

f. Determine the sieve size weights retained for each aggregate component by multiplying the aggregate's hot bin or composite average percent retained by the total weight (grams batched) for that aggregate component (from e above) in the specimen. An additon check should be performed. Any accumulative differences found from the actual total weight retained and the grams batched should be compensated for in the size fraction having the most material.

g. Using a scale of approved sensitivety and accuracy (readable and sensitive to 0.1 gram, and accurate to a minimum of 0.1 gram and to a maximum of 0.05% of test load, or one gram, whichever is smaller) zero the tare weight and begin weighing each aggregate component (BIN) sieve size weight retained separately.

h. After weighing each aggregate component, as described in (g above, combine all aggregate components to determine the total aggregate specimen weight. This total weight must equal the predetermined total grams batched weight for the specimen within ± three grams. If outside these limits the specimen shall be discarded.

C. <u>Batching and Compacting Marshall Specimens</u>

1. Heat all specimen aggregate samples to a temperature of 350°F. Due to temperature variations that may occur within an oven a thermometer should be placed in each of the aggregate samples while the material is heated to ensure that the aggregate temperature achieves 350°F. Implements used for mixing should also be preheated. Also preheat the Marshall hammer on a hot plate preheated to approximately 300°F. Mechanical or hand mixing may be used; however hand mixing is recommended because of the difficulty in cleaning the mechanical wire comb mixing paddles.

2. Bring the asphalt cement to temperature by means of an approved constant temperature heating mantle or oven. The asphalt cement temperature should be 300 to 315°F. The temperature of the asphalt cement should be checked periodically. If the A.C. temperature exceeds 325°F the sample of asphalt cement should be discarded. Precaution should also be taken to prevent altering of the asphalt cement characteristics by prolonged heating and/or reheating. The asphalt cement should not be held at the mixing temperature for more than one hour before using. Open containers should not be used for heating asphalt cement. Containers with friction top lids with a punctured hole for pouring is recommended.

3. The following batching/mixing procedure must take no more than 5.5 minutes.

   a. Remove the mixing bowl from the oven and determine tare weight. If bowl is being used for first time, the inside should be lightly coated, using an asphalt cement and aggregate mixture, prior to batching the first specimen. Add the preweighed aggregate to the bowl. Dry mix the combined aggregate, being carefull to lose as little dust as possible and ensuring a uniform mixture, and form a crater in the center of the aggregate mound. Record weight of aggregate and bowl. After determining the actual weight of the aggregate, by subtracting the bowl tare weight, calculate the total specimen weight as follows:

$$\text{Total Specimen Weight, gms.} = 100\left[\frac{\text{Actual Aggregate Weight, gms.}}{\text{\% Aggregate Total Mix}}\right]$$

eg. Actual Aggregate Weight = 1127.2 grams

% Asphalt Cement Desired = 6.0%

% Aggregate Total Mix = 94.0%

$$\text{Total Specimen Weight, gms} = 100\left[\frac{1127.2}{94.0}\right]$$

Total Specimen Weight, gms. = 1198.9 gms.

b. The scale should be set to the total specimen weight plus bowl tare weight. Next add sufficient asphalt cement to balance the scale. Care should be taken to weigh proper quantity of asphalt cement, however excess can be removed by absorption with paper towels. Care should be taken not to remove fines.

c. Remove bowl from scale and commence mixing. Mix until all particles are coated or until two minutes have elapsed. If all particles are not coated after two minutes of mixing (proper coating is difficult at the low asphalt cement percentages) the mixing bowl and its contents must be placed in the oven and its temperature checked. If the temperature is below 275°F the mix must remain in the oven until the mix becomes 275°F or above, and then mixing may be resumed. Final mixing temperature in bowl shall not exceed 315°F.

d. Using a steel compaction mold, preheated to approximately 300°F, insert a filter disc onto the base plate. Next, spoon the bituminous mix into the mold from the mixing bowl being careful not to lose material or cause segregation.

e. Spade the mold 25 times with a hot spatula, 15 times around the perimeter and ten times over the interior. The material should be slightly crowned in the center of the mold.

f. Immediately insert two thermometers into the mold, one at the center of the molded material and the other one-quarter inch in from one edge. Cover the top of the mold as well as possible with gloved hands to prevent heat loss.

g. Target temperature for compaction is as follows:

AC 15 or 85 - 100 PEN	270°F ±5°F
AC 20	275°F ±5°F

Compaction shall begin when the average of the two thermometer readings are within the temperature range prescribed above. Place paper disc on top of the spaded mix prior to compaction. If the mix temperature is below those limits listed above the samples should not be compacted. These samples may be used for determining the Maximum Theoretical Specific Gravity - ASTM D2041 "Rice Test". This test is run on uncompacted specimens.

h. A mechanical hammer should be used for compaction. Hand hammers will generally result in a different compaction effort. Therefore to avoid a lack of uniformity in design submissions we recommend the use of a mechanical hammer. The compaction apparatus must meet the requirements of ASTM D1559 Section 2. Apparatus.

   The mechanical hammer is to be held rigidly straight and stable on top of the mixture by means of appropriate supports and weights. The mechanical hammer must not "jump" or move about on the surface of the mixture. Its base plate may not rotate. The mechanical hammer must be as devoid as possible of any motion except the smooth rise and fall of the hammer. The chain drive shall be properly adjusted for tension. It is recommended that similar model mechanical hammers be used to achieve acceptable lab to lab repeatability.

i. The compactive effort shall be 50 blows per side.

j. Times for each phase of mold preparation:

Batching (asphalt & aggregate combination):	1 min.
Mixing:	2 min.
Compaction:	2 1/2 min.

k. The total 5.5 minute time frame for specimen preparation listed above can be realized only if the bituminous mixture reaches the compaction range temperature prescribed for it almost immediately upon placement in the mold.

   Should the temperature of the bituminous mixture in the compaction mold exceed the limits prescribed for it, allow the material to cool at ambient temperature until it reaches the specified temperature range.

l. As soon as the compaction process is complete, remove the filter discs from each side of the specimen.

m. Allow the specimen to cool in air (cool enough to be held in a bare hand) until no deformation will result when removing it from the mold. Extract the specimen from the mold by means of an extrusion jack or other compression device. Then place the specimen on a smooth, level surface.

D. Testing of Marshall Specimens

Specimens must be cooled to room temperature prior to testing. Specimens are generally allowed to cool overnight. When more rapid cooling is desired table fans may be used; specimens may be cooled in cold water provided the specimen is sealed inside a plastic bag; specimens may also be cooled in a 40°F - 50°F refrigerator.

In the Marshall Design specimens are subjected to the following tests in the order listed:

1. Bulk Specific Gravity Determination (ASTM D2726)
2. Maximum Theoretical Specific Gravity Determination (ASTM D2041)
3. Stability and Flow Tests
4. Air Voids

This Marshall data is to be documented on Department forms BR-76, 77 and 79 as shown in Figure V-D-1 through V-D-3.

1. Bulk Specific Gravity Determination

   The bulk specific gravity test may be performed as soon as the freshly compacted specimens have cooled to room temperature.

   A balance with ample capacity, readable and sensitive to 0.1 gram and accurate to a minimum of 0.1 gram and to a maximum of 0.05% of the test load, or one gram, whichever is smaller, is required. The resultant bulk specific gravity should be calculated to three decimal places. Specific gravity values that result in a range greater than 0.02 within the same asphalt cement content should be considered invalid and not included in the data averaging. Invalid specimens shall be re-done. The test procedure for bulk specific gravity should be done according to ASTM D2726 "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens". The following highlights details of this test:

   a. Weight of Dry Specimen in Air - weigh the specimen after it has been standing in air at room temperature for at least one hour. Designate this weight as A.

   b. Weight of Specimen in Water - Immerse the specimen in a water bath at 77F (25C) for 3 to 5 minutes and then weigh in water. The water bath must be equipped with an overflow spout to maintain constant water level during weighing. Spout must have ceased to drip before weight is read from scale. Designate this weight as C.

   c. Weight of Saturated Surface Dry Specimen in Air - After removing specimen from water bath, surface dry the specimen by blotting quickly with a damp towel and then weigh in air. Designate this weight as B.

   d. Calculate the bulk specific gravity of the specimen as follows:

      $Gmb = A/(B-C)$

      where:

      Gmb = bulk specific gravity of specimen
      A = weight of the dry specimen in air, g
      B = weight of the saturated surface dry specimen in air, g and
      C = weight of specimen in water, g

      NOTE: All weight measurements must be recorded to the nearest tenth of a gram.

2. Maximum Theoretical Specific Gravity Determination

   This test procedure must be done in accordance with ASTM D2041 "Theoretical Maximum Specific Gravity of Bituminous Mixture". The following highlight details of this test:

   a. Test must be run on uncompacted Marshall specimens.

   b. Test shall be conducted on a minimum of two specimens at each asphalt cement content.

   c. A 2000 ml (2 quart) pycometer or flask should be used.

d. A scale readable and sensitive to 0.1 gram, and accurate to a minimum of 0.01 gram and to a maximum of 0.05 % of the test load, or one gram, whichever is smaller, is required.

e. A constant vacuum must be maintained in the flask at all times. The vacuum level required must be a minimum of 28.7 inches (730 mm) Hg. This level of vacuum is virtually impossible to maintain by any other means than a precision vacuum pump. The 28.7 inch vacuum level is a minimum; a lesser level of vacuum invalidates test results.

f. Specific gravity results difference by more than 0.011 at the same asphalt cement content should be considered invalid and run again.

g. Test procedure:

(1). Calibration of Flask. Calibrate the volumetric flask by accurately determining the mass of de-aired water at 77$\pm$0.9F (25$\pm$0.5C) required to fill it. This weight should be recorded as "D". The de-aired water is accomplished by applying a minimum 28.7 inch vacuum for fifteen (15) minutes. The flask filled with water should be jarred, rolled, etc. every two minutes to assist in releasing bubbles from the water. Care must be taken in handling the flask under vacuum to prevent breakage. The flask shall be sufficiently strong to withstand an essentially full vacuum. After de-airing the 77F water in the flask, the rubber stopper must be removed and the remaining portion of the flask filled with de-aired 77F water. A glass plate should be used to ensure accurate filling of the flask.

While the calibration of the flask need be done only once, the calibration should be checked occassionally, The equipment must be kept clean and free of any accumulation that would change the mass if the volume calibration is to remain constant. Care should be taken to use suitable solvents, especially with plastic containers, and glass vessels should not be subjected to high vacuum if they have been scratched or damaged in any way.

(2). Separate the particles of the sample, taking care not to fracture the mineral particles, so that particles of the fine aggregate portion are not larger than 1/4 inch. If the mixture is not sufficiently soft to separate manually, place it in a large flat pan and warm in an oven only until it can be so handled.

(3). Cool the sample to room temperature, and weigh either prior to or after placing in an empty calibrated flask. Designate the net mass of sample as A. If sample is weighed prior to placing in flask, care must be taken to get the entire sample into the flask.

(4). Add sufficient water at approximately 77F (25F) to cover the sample. Remove the entrapped air by subjecting the contents to a minimum vacuum of 28.7 inches for fifteen (15) minutes. Agitate the container and contents either continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes. Glass vessels should be handled on a resilient surface, such as rubber or plastic mat, and not on a hard surface, to avoid impact while under vacuum. Vacuum should be applied and released gradually by using a bleed valve.

NOTE: The release of entrapped air must be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.01 percent or 1 ml of 10 percent solution in 1000 ml of water (3 drops).

Water used to conduct test shall not contain impurities. Municipal sources are considered acceptable sources.

(5). Fill the remaining portion of the flask with de-aired water at approximately 77F (25C) and bring contents to a temperature of 77$\pm$1.8F (25$\pm$1C) in a waterbath. Determine the mass of the container (including glass plate, if used) and contents by weighing 10$\pm$1 minutes after completing the de-airing operation explained in Step 4 above. Designate this mass as E.

(6). Calculate the specific gravity of the sample as follows:

$$G_{mm} = \frac{A}{A+D-E}$$

where:

G_{mm} = Maximum theoretical specific gravity of bituminous mixture

A = mass of dry sample in air

D = mass of container filled with water at 77F (25C)

and

E = mass of container filled with water and sample at 77F (25C)

NOTE: All weight measurements must be recorded to the nearest tenth of gram.

Figure V-D-3 shows typical "Rice Method" worksheet, BR-76.

3. Stability and Flow Determination

After the bulk specific gravity has been determined for the test specimens, the stability and flow tests are to be performed as per ASTM D1559 "Resistance to Plastic Flow of Bituminous Mixtures using Marshall Appartus". The following highlights the details of this test:

a. Immerse specimen in water bath at 140F $\pm$ 1.8F (60C$\pm$1C) for 30 to 40 minutes before test.

b. Thoroughly clean inside surfaces of testing head. Temperature of head shall be maintained at 70 to 100F (21 to 37.8C). Lubricate guide rods with a thin film of oil so that upper test head will slide freely without binding. If a proving ring is used to measure applied load, check to see that dial indicator is firmly fixed and "zeroed" for the "no-load" position.

c. With testing apparatus in readiness, remove test specimen from water bath and carefully dry surface by blotting with a twoel. Place specimen in lower testing head and center; then fit upper testing head into position and center complete assembly in loading device. Paper towels or other similar products shall not be placed around the specimen during testing. Place flow meter over marked guide rod as noted below. Be sure to zero flow meter prior to start of test.

NOTE: When aligning the upper testing head with the lower testing head, the guide post marked with a number should be aligned with the side of the upper segment also marked with a corresponding number. The flow meter should be placed over the marked guide rod.

d. Apply testing load to specimen at constant rate of deformation, 2 inches (51 mm) per minute, until failure occurs. The point of failure is defined by the maximum load reading obtained. The total number of pounds required to produce failure of the specimen at 140F (60C) shall be recorded as its Marshall Stability value.

e. While the stability test is in progress, hold the flow meter firmly in position over the marked guide rod and remove immediately as the load begins to decrease; take reading and record. This reading is the flow value for the specimen, expressed in units of 1/100 inch. For example, if the specimen deformed 0.15 inch, the flow value is 15.

f. The entire procedure, both stability and flow tests, starting with the removal of the specimen from the water bath shall be completed within a period of thirty seconds.

g. The actual stability value obtained shall be corrected when required, due to volume differences. The correlation ratios in Appendix 3 should be used to correct stability values on a volumetric basis.

4. Density and Air Voids Determination. After the completion of the tests to determine the bulk specific gravity, maximum specific gravity, stability and flow values, a density and voids analysis is made for each asphalt content series of test specimens as follows:

Density Determination:

a. Average the bulk specific gravity values, G_{mb}, for all test specimens at given asphalt cement content. Values obviously in error shall not be included in the average. Specimens with specific gravity values resulting in a range of more than 0.02 shall be considered invalid and shall be redone.

b. Determine average unit weight for each asphalt cement content by multiplying the average bulk specific gravity by 62.4 $lb/ft.^3$.

BR 79 (3/81)
COMPUTATION OF MARSHALL
MIX PROPERTIES

20

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ITEM 18403.1711 REGION 11 .

MIX TYPE 6F

PRODUCER XYZ BIT. CORP. LOCATION SMITHTOWN

Specimen	Asphalt Content	Weight - Grams In Air	Weight - Grams In Water	Weight - Grams S.S.D.	Volume CC	Specific Gravity Bulk G_{mb}	Specific Gravity Theor. G_{mm}	Voids Total Mix	Unit Wt. Lb/Cu Ft	Stability-Lb Measured	Stability-Lb Corrected	Flow 1/100 Inch
a	b	c	d	e	f	g	h	i	j	k	l	m
					(e-d)	$\frac{c}{f}$		$100\frac{(h-g)}{h}$	(gX62.4)			
A	5.0	1163.6	663.6	1172.2	508.6	2.287				1530	1530	12
B	5.0	1168.0	665.4	1180.6	515.2	2.267				1320	1320	13
C	5.0	1162.0	663.3	1172.2	508.9	2.283				1480	1480	13
AVG.	5.0					2.279	2.445	6.79	142.2		1443	13
A	5.5	1160.5	664.8	1167.6	502.8	2.308				1640	1706	14
B	5.5	1161.1	670.8	1171.7	500.9	2.318				1670	1737	13
C	5.5	1246.3	723.3	1261.9	538.6	2.314				1780	1655	14
AVG.	5.5					2.313	2.421	4.67	144.3		1700	14
A	6.0	1189.6	683.6	1194.6	511.0	2.328				1790	1790	15
B	6.0	1168.4	667.9	1169.4	501.5	2.330				1750	1820	15
C	6.0	1121.2	644.1	1122.1	478.0	2.346				1710	1949	14
AVG.	6.0					2.335	2.405	2.91	145.7		1853	15
A	6.5	1155.9	665.0	1157.7	492.7	2.346				1760	1918	16
B	6.5	1128.1	648.7	1129.8	481.1	2.345				1620	1847	15
C	6.5	1144.9	657.6	1145.4	487.8	2.347				1800	1962	16
AVG.	6.5					2.346	2.379	1.39	146.4		1909	16
A	7.0	1103.0	634.1	1105.4	471.3	2.340				1550	1767	16
B	7.0	1124.7	645.7	1126.3	480.6	2.340				1560	1778	16
C	7.0	1129.8	647.9	1131.3	483.4	2.337				1550	1690	18
AVG.	7.0					2.339	2.360	0.89	146.0		1745	17

FIGURE V-D-1

PREPARED BY J. BUSHEY ON 1/21/81

BR-77 (3/81)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ITEM 18403.1711 REGION 11

MIX TYPE 6F

PRODUCER XYZ BIT. CORP.

LOCATION SMITHTOWN, NY

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE
(Analysis by weight of total mixture)

COMPOSITION OF PAVING MIXTURE

Constituent Material		N.Y.S. D.O.T. Source Number	N.Y.S. D.O.T. Test Number	Specific Gravity, G: Apparent	Specific Gravity, G: Bulk		Mix Composition, % by weight of Total Mix, P — Mix or Trial Number 1	2	3	4	5
Course Aggregate	No. 1 Stone	9-6R	78AR19	2.707	2.635	P_1			8.4		
	No. 1 Non-Carbonate Stone	1-9G	78AG10C	2.692	2.604	P_2			12.6		
	No. 1A Stone	9-6R	78AR19	2.707	2.635	P_3			33.0		
	1A Non-Carbonate Stone					P_4					
Fine Aggregate	Manufactured	9-6R	78AR19	2.707	2.635	P_5			20.0		
	Natural	9-9F	78AF27	2.698	2.571	P_6			20.0		
MINERAL FILLER						P_7					
TOTAL AGGREGATE						P_s			94.0		
ASPHALT CEMENT @ 77 F (25C)				1.021		P_B			6.0		

Symbol	Property	Equations*	1	2	3	4	5
G_{mm}	Max. Sp. Gr. (G_{mm}) Paving Mix (ASTM D2041)				2.405		
G_{mb}	Bulk Sp. Gr. (G_{mb}) compacted mix (ASTM D2726)	—			2.335		
G_{sb}	Bulk Sp. Gr. (G_{sb}) total aggregate	(1)			2.617		
G_{se}	Effective Sp. Gr. (G_{se}) total aggregate	(2)			2.633		
G_{sa}	Apparent Sp. Gr. (G_{sa}) total aggregate	(1)			2.703		
VMA	$VMA = 100 - \left(\frac{G_{mb} \times P_s}{G_{sb}}\right)$	(3)			16.13		
P_a	Air Voids (P_a) $= 100\left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right)$	(4)			2.91		
P_{vma}	%VMA filled w/A.C. (P_{vma}) $= 100\left(\frac{VMA - P_a}{VMA}\right)$	(5)			81.96		
P_{be}	Effective Asphalt Content (P_{be}) $= \frac{G_b(VMA - P_a)}{G_{mb}}$	(6)			5.78		
	Stability [Marshall]	—			1853		
	Flow [Marshall]	—			15		

*EQUATIONS FROM CHAPTER V, SECTION E, NY MATERIALS METHOD 5.13

FIGURE V-D-2

Prepared By J. BUSHEY on 1/21/81

BR 76 (3/81)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

MIX TYPE 6F REGION 11

PRODUCER XYZ BIT. CORP.

LOCATION SMITHTOWN, NY

MAXIMUM SPECIFIC GRAVITY OF BITUMINOUS PAVING MIXTURES
ASTM D-2041 (RICE METHOD)

A= Weight of dry sample in air (grams)
D= Weight of flask filled with airless water at 77°F (25°C) grams
E= Weight of flask filled with water and sample at 77°F (25°C) grams

$$MTSG = \frac{A}{A+D-E}$$

ASPHALT CONTENT	5.0 %		5.5 %		6.0 %		6.5 %		7.0 %	
TEST NO.	1	2	1	2	1	2	1	2	1	2
A	1188.4	1179.4	1194.2	1190.6	1182.4	1187.6	1184.6	1190.3	1178.8	1183.5
D	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6
E	3361.3	3357.2	3360.3	3358.6	3350.4	3353.4	3345.4	3350.4	3338.7	3341.8
A + D - E	486.7	481.8	493.5	491.6	491.6	493.8	498.8	499.5	499.7	501.3
MTSG	2.442	2.448	2.420	2.422	2.405	2.405	2.375	2.383	2.359	2.361
Average MTSG	2.445		2.421		2.405		2.379		2.360	

Test By J. BUSHEY on 1/21/81

FIGURE V-D-3

Air Void Determination:

The air voids, P_a, in a compacted paving mixture consist of the small air spaces between the coated aggregate particles.

Using the average bulk specific gravity and the average maximum theoretical specific gravity of the Marshall specimens at each asphalt cement content, calculate the void content of the specimens as follows:

$$P_a = 100\left[\frac{G_{mm}-G_{mb}}{G_{mm}}\right]$$

where:

P_a = air voids in compacted mixture, percent of total volume reported to to the nearest 0.01%.

G_{mm} = maximum specific gravity of bituminous mixture

G_{mb} = bulk specific gravity of compacted specimen

Calculation using data from FIGURE V D-2 at 6.0% A.C.

$$P_a = 100\left[\frac{2.405 - 2.335}{2.405}\right] = 2.91$$

E. Analysis of Marshall Specimens

1. Definition of Terms

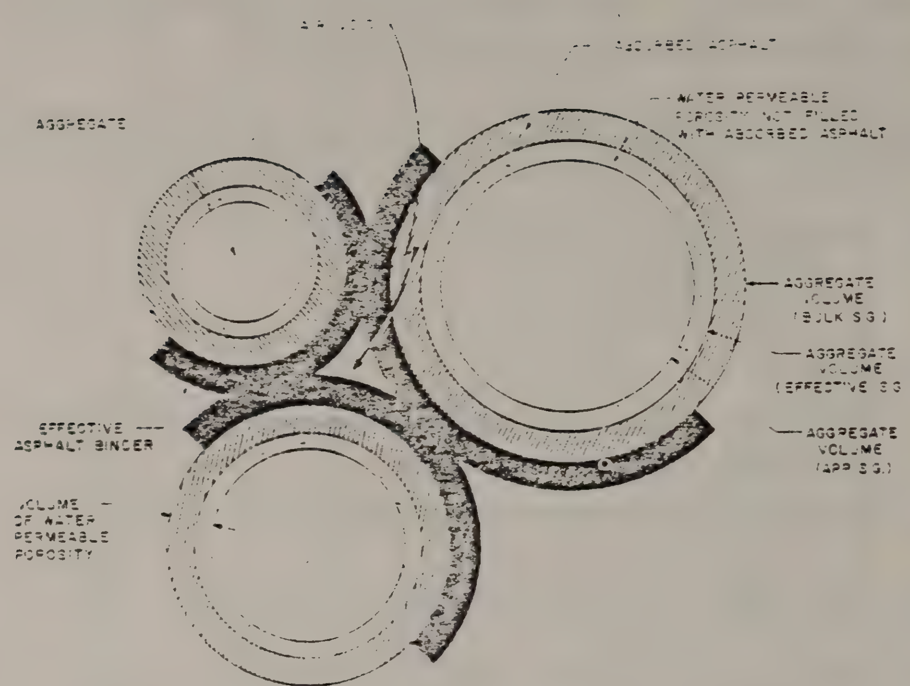
The terms effective asphalt content (P_{be}), air voids (P_a), voids in the mineral aggregate (VMA), and voids in the mineral aggregate filled with asphalt cement (P_{VMA}) will be used throughout this chapter, and are defined as follows: See FIGURE V-E-1 and 2.

Effective Asphalt Content, P_{be} - the total asphalt cement content of a paving mixture minus the portion of asphalt cement that is lost by absorption into the aggregate particles.

Air Voids, P_a - the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture.

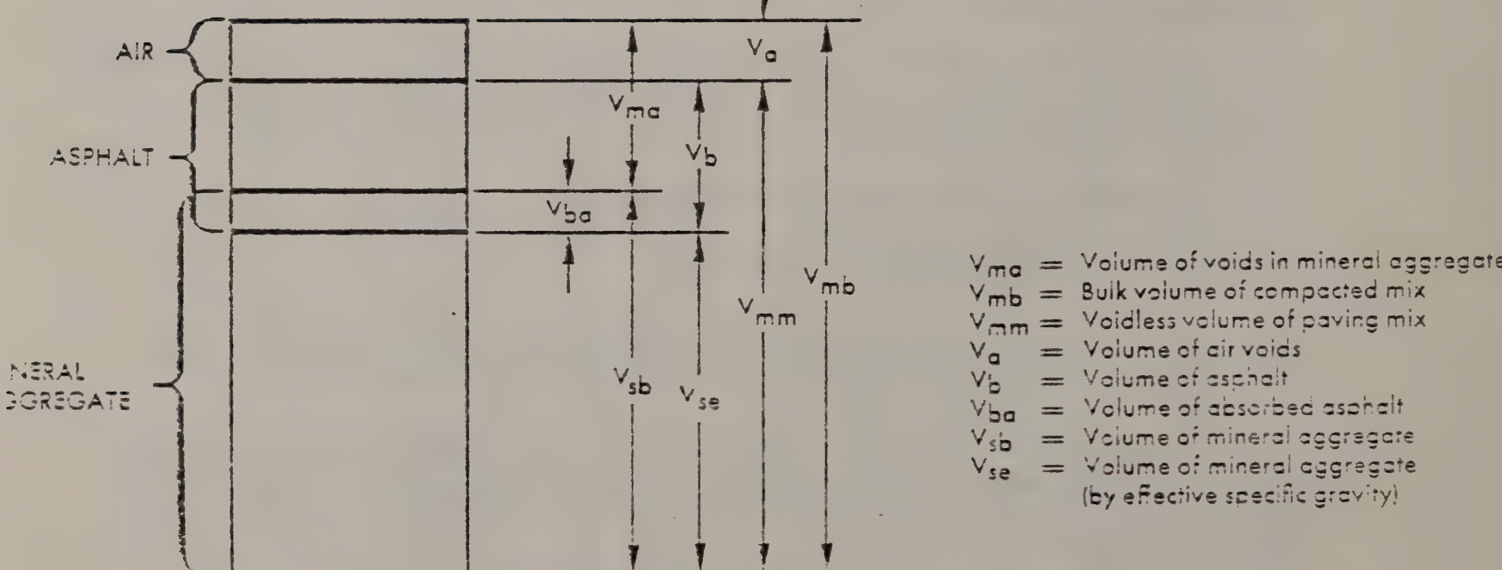
Voids in the Mineral Aggregate, VMA - the volume of interangular void space between the aggregate particles of a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume of the sample.

VMA filled with asphalt, P_{VMA} - the ratio of volume of effective asphalt content, P_{be}, to the volume of voids in the mineral aggregate, VMA, expressed as a percent.



Illustrating VMA, air voids and effective asphalt content
in compacted asphalt paving mixture

Figure V-E-1



Representation of volumes in a compacted asphalt specimen

Figure V-E-2

Values for VMA and percent VMA filled with asphalt of compacted Marshall specimens should be calculated in terms of the aggregate's bulk specific gravity, G_{sb}, with an allowance for the portion of the asphalt binder lost by absorption into the aggregate particles.

Mineral aggregates are porous and can absorb water and asphalt to a variable degree. Furthermore, the ratio of water to asphalt cement absorption varies with each aggregate. Three methods of measuring aggregate specific gravity take these absorption variations into consideration. They are ASTM bulk, ASTM apparent, and effective specific gravities, and these are defined as follows: See Figure V E-1.

Bulk Specific Gravity, G_{sb} - the ratio of the weight in air of a unit volume of permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature.

Apparent Specific Gravity, G_{sa} - the ratio of the weight in air of a unit volume of an impermeable material at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature.

Effective Specific Gravity, G_{se} - the ratio of the weight in air of a unit volume of a permeable material (excluding voids permeable to asphalt) at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature.

NOTE: The volume of asphalt cement binder absorbed by an aggregate is invariably less than the volume of water absorbed. Consequently, the value for the effective specific gravity of an aggregate should be between its bulk and apparent specific gravities. When the effective specific gravity falls outside these limits, its value must be assumed to be incorrect. The calculations, the maximum specific gravity of the total mix by ASTM D2041, and the composition of the mix in terms of aggregate and total asphalt cement content should be rechecked for the source of error.

2. Relationship to Pavement Performance

Analysis of voids in the mineral aggregate (VMA) and percent VMA filled with asphalt are the best measurements available to determine (indirectly) asphalt cement film thickness.

In order for a bituminous pavement to be durable a minimum quantity of asphalt cement is required to attain adequate film thickness on the aggregate particles. If a bituminous mix is prepared with an insufficient asphalt cement film thickness, premature pavement failure will result because the asphalt cement will oxidize or harden at an accelerated rate.

If an excess quantity of asphalt cement is used, the mix may become unstable and result in pavement flushing. In order to avoid both these pavement problems, a minimum and maximum value of percent VMA filled with asphalt cement must be considered.

The following limits have proven to result in an acceptable paving mixture, and these values should be used as guidelines when designing and producing a bituminous mixture:

Mix Type	VMA (Minimum)	% VMA Filled with Asphalt MIN.	MAX.
6F	16	75	88
7F	17	76	88
8F	17	76	88

Generally, Marshall determination of the optimum asphalt cement content will result in a bituminous mixture having an acceptable VMA and percent VMA filled with asphalt. If it does not an asphalt cement content or aggregate adjustment may be required.

3. Analysis Procedure

The following analysis should be documented on Department Form BR-77. Figure V D-1 shows a typical analysis at 6.0% asphalt cement.

a. Individual Material Constituent Specific Gravity Determination.

Measure the bulk and apparent specific gravities of the coarse aggregate (ASTM C127) and of fine aggregate (ASTM C128). These values have been determined and are listed for each aggregate source in the Department's "Approved Sources of Fine and Coarse Aggregates" published by the Materials Bureau.

The apparent specific gravities of the asphalt cement (ASTM D70) and of the mineral filler (ASTM D854) may be obtained from the supplier of these materials. The asphalt cement specific gravity is generally given at 60F (16C). In order to convert this specific gravity to 77F (25C) a factor of 0.9941 should be applied. Specific gravity at 77F (25C) is needed for bituminous mix design.

b. Composite Aggregate Bulk and Apparent Specific Gravity Determination.

When the total aggregate consists of separate fractions of coarse and fine aggregate and mineral filler, all having different specific gravities, the bulk and apparent specific gravities for the total aggregate are calculated as follows:

Bulk Specific Gravity, G_{sb} or Apparent Specific Gravity, G_{sa}

$$G_{sb} \text{ or } G_{sa} = \left[\frac{P1 + P2 + \ldots + Pn}{\frac{P1}{G1} + \frac{P2}{Gw} + \ldots + \frac{Pn}{Gn}}\right] \qquad (1)$$

where:

G_{sb} = Bulk specific gravity for the total aggregate.

G_{sa} = Apparent specific gravity for the total aggregate

P1, P2, Pn = Percentages by weight of aggregates, 1, 2, n; and

G1, G2, Gn = Bulk or apparent (whichever is applicable) specific gravities of aggregates

Since the bulk specific gravity of mineral filler is difficult to determine the apparent specific gravity is used instead. The error is usually negiligible due to the small quantity of mineral filler in the bituminous mixture.

Calculation using the data in FIGURE V-D-2 at 6.0% A.C.

$$G_{sb} = \left[\frac{8.4 + 12.6 + 33.0 + 20.0 + 20.0}{\frac{8.4}{2.635} + \frac{12.6}{2.604} + \frac{33.0}{2.635} + \frac{20.0}{2.635} + \frac{20.0}{2.571}}\right] = 2.617$$

c. Effective Specific Gravity of Aggregate Determination.

This is based on the maximum specific gravity of a paving mixture, G_{mm} ASTM D2041. The effective specific gravity, G_{se}, of the combined aggregates includes all void spaces in the aggregate particles except those that absorb asphalt cement. The G_{se} is calculated as follows:

$$G_{se} = \left[\frac{P_{mm} - P_b}{\frac{P_{mm}}{G_{mm}} - \frac{P_b}{G_b}}\right] \qquad (2)$$

where:

G_{se} = effective specific gravity of combined aggregate.

P_{mm} = total loose mixture, percent by total weight of mixture = 100 percen

P_b = asphalt cement, percent by total weight of mixture.

G_{mm} = maximum specific gravity of paving mixture (no air voids), ASTM D204

G_b = specific gravity of asphalt at 77F (25C).

Calculation using the data in FIGURE V-D-2 at 6.0% A.C.

$$G_{se} = \left[\frac{100.0 - 6.0}{\frac{100.0}{2.405} - \frac{6.0}{1.021}}\right] = 2.633$$

d. Percent VMA Determination.

The VMA is calculated on the basis of the bulk specific gravity of the aggregate, G_{sb}, and is expressed as a percentage of the bulk volume of the compacted paving mixture, G_{mb}. The VMA is calculated as follows:

$$VMA = 100 - \left[\frac{G_{mb}\,P_s}{G_{sb}}\right] \qquad (3)$$

where:

VMA = voids in mineral aggregate (percent of bulk volume)

G_{sb} = bulk specific gravity of aggregate

G_{mb} = bulk specific gravity of compacted mixture (ASTM D2726)

P_s = aggregate, percent by total weight of mixture

Calculation using data from FIGURE V-D-2 at 6.0% A.C.

$$VMA = 100 - \left[\frac{2.335 \times 94.0}{2.617}\right] = 16.13$$

e. Percent Air Voids Determination.

The percentage of air voids P_a in a compacted mixture is calculated as follows:

$$P_a = 100\left[\frac{G_{mm} - G_{mb}}{G_{mm}}\right] \qquad (4)$$

where:

P_a = air voids in compacted mixture, percent of total volume

G_{mm} = maximum specific gravity of paving mixture (ASTM D2041)

G_{mb} = bulk specific gravity of compacted mixture

Calculation using data from FIGURE V-D-2 at 6.0% A.C.

$$P_a = 100\left[\frac{2.405 - 2.335}{2.405}\right] = 2.91$$

f. Percent VMA Filled with Asphalt Determination.

The P_{VMA} is calculated as follows:

$$P_{VMA} = 100\left[\frac{VMA - P_a}{VMA}\right] \qquad (5)$$

where:

P_{VMA} = percent VMA filled with asphalt

VMA = voids in mineral aggregate

P_a = air voids in compacted mixture, percent of total volume

Calculations using data in FIGURE V-D-2 at 6.0% A.C.

$$P_{VMA} = 100\left[\frac{16.13 - 2.91}{16.13}\right] = 81.96$$

g. Effective Asphalt Cement Content Determination.

The effective asphalt cement content, P_{be}, of a paving mixture is the portion of the total asphalt cement content that remains as a coating on the outside of the aggregate particles, and is the asphalt cement content on which service performance of a bituminous paving mixture depends. The P_{be} is calculated as follows:

$$P_{be} = \frac{G_b\,(VMA - P_a)}{G_{mb}} \qquad (6)$$

where:

P_{be} = effective asphalt cement content, percent by total weight of mixture

G_b = specific gravity of asphalt cement at 77F (25C)

VMA = voids in mineral aggregate

P_a = air voids in compacted mixture, percent of total volume

G_{mb} = bulk specific gravity of compacted mixture

Calculation using data from FIGURE V-D-2 at 6.0% A.C.

$$P_{be} = \frac{1.021\,(16.13 - 2.91)}{2.335} = 5.78$$

F. Marshall Curves and Selecting Asphalt Cement Contents

1. Curve Preparation

For inclusion in the Mix Design submission the Producer shall prepare a separate graphical plot for the following values as illustrated in FIGURE V-F-1, BR-78.

Stability vs Asphalt Content
Flow vs Asphalt Content
Unit Weight of Total Mix vs Asphalt Content
Percent Air Voids vs Asphalt Content
Percent Voids in Mineral Aggregate (VMA) vs Asphalt Content
Percent VMA filled with Asphalt vs Asphalt Content

In each graphical plot connect the plotted values with a smooth curve that obtains the "best fit" for all values. The plotted values should be the average of those test values obtained at each asphalt cement content.

2. Curve Trends and Relations

The test property curves, plotted as described above, have been found to follow a reasonably consistent pattern for dense-graded asphaltic paving mixes. Trends generally noted are outlined as follows:

a. The stability value increases with increasing asphalt cement content up to a maximum after which the stability decreases.

b. The flow value increases with increasing asphalt cement content.

c. The curve for unit weight of total mix is similar to the stability curve, except that the maximum unit weight normally (but not always) occurs at a slightly higher asphalt cement content than the maximum stability.

d. The percent air voids decreases with increasing asphalt cement content, ultimately approaching a minimum void content.

e. The percent voids in the mineral aggregate generally decreases to a minimum value then increases with increasing asphalt cement content.

f. The percent VMA filled with asphalt increases with increasing asphalt cement content, ultimately approaching a maximum value.

3. Determination of Optimum Asphalt Cement Content

The optimum asphalt cement content of the bituminous paving mix is determined by the Producer from Marshall curve data. Consideration is given to three of the test property curves illustrated in FIGURE V-F-1 in making this determination. From these data curves, asphalt cement contents are determined which yield the following:

(1). Maximum stability

(2). Maximum unit weight

(3). Specified median percent air voids

The optimum asphalt cement content of the mix is then the numerical average of the values for the asphalt cement contents determined as noted above.

Calculation of optimum asphalt cement content using data in FIGURE V-F-1 is as follows:

	PERCENT
(1). Asphalt Content at Maximum Unit Weight	6.5
(2). Asphalt Content providing 3 percent air voids (median for 2 to 4 percent spec. range)	6.0
(3). Asphalt Content at maximum stability	6.5
(4). Optimum asphalt content, average	6.3

BR-78 (3/81)

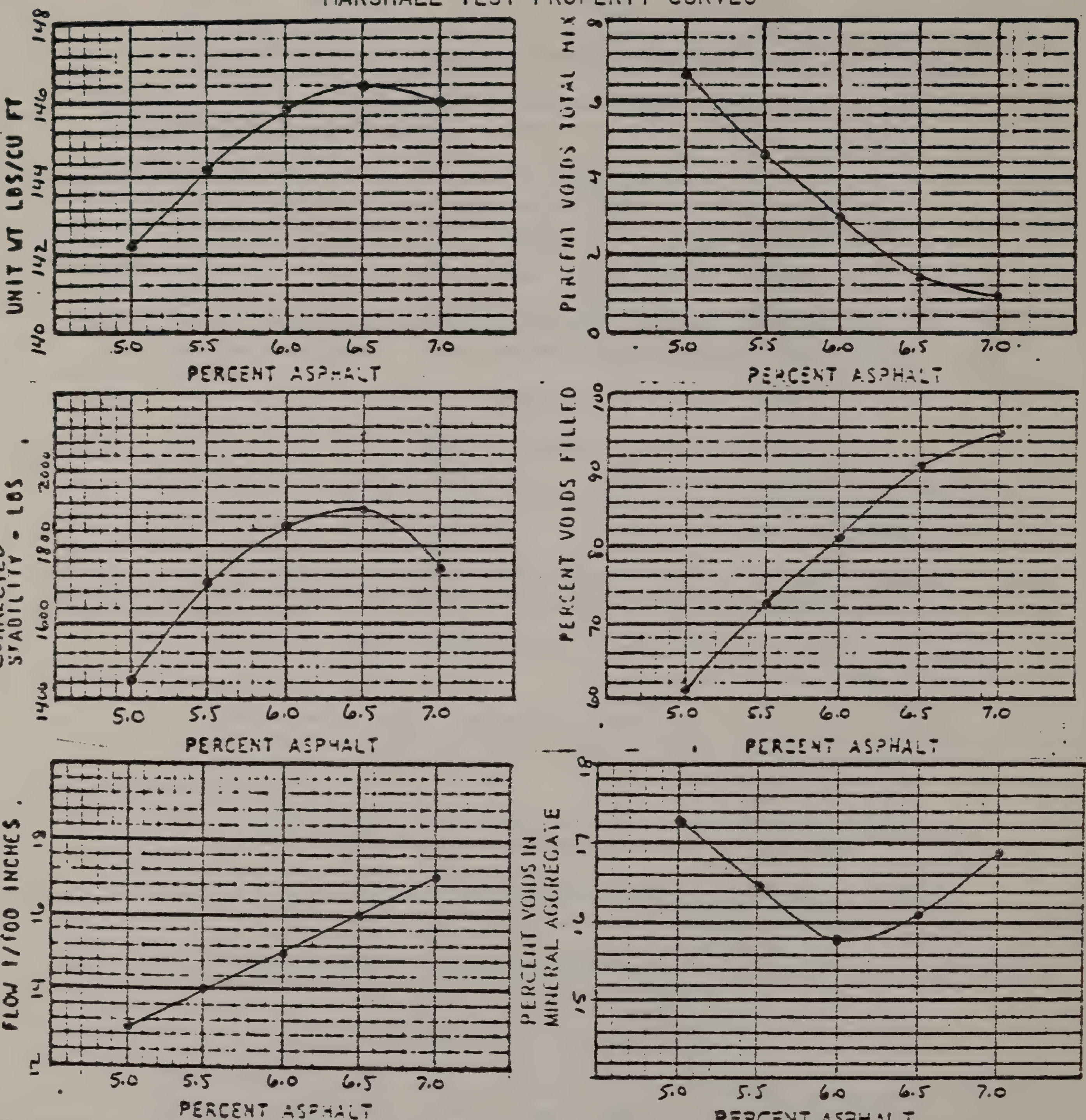
NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

REGION 11

MIX TYPE 6F

Producer XYZ BIT. CORP. Location SMITHTOWN, NY

MARSHALL TEST PROPERTY CURVES



PROPERTY	STABILITY	UNIT WT.	AIR VOIDS
PT. ON CURVE	PEAK	PEAK	@ 3.0%
% ASPHALT	6.5	6.5	6.0

TEST BY J. BUSHEY

DATE 1/21/81

VALUES AT OPTIMUM 6.3

PROPERTY	STABILITY	UNIT WT	AIR VOIDS	FLOW	VMA	VOIDS FILLED
SPEC.	1500 MIN *	N/A	2.0-4.0%	3-18	N/A	N/A
ACTUAL	1900	146.3	2.0	15	15.9	88

* 1200 # Min. for Mixes using Long Island Natural Sand

FIGURE V-F-1

VI. EVALUATION OF MARSHALL DATA - DEPARTMENT REVIEW

The Department will review the submitted design for completeness, accuracy and interpretation of data. Verification of the submitted test properties, at selected asphalt contents, will generally be performed to verify that proper lab technique was used to generate the data.

The Department will check the submitted Marshall properties at the optimum asphalt cement content to determine that all specified Marshall criteria are met. If all specified properties are not met, the submitted optimum asphalt cement content will be adjusted so that all properties are met.

The Department will check the Marshall data and resultant curves to determine if they follow the expected trends as described in Section V-F. If not, the curves can not be used to determine the optimum asphalt cement content. Under this circumstance, the submitted Marshall data may still be used by the Department to aid in selecting the production asphalt cement content. However, if in the opinion of the Department the inaccurate Marshall curves resulted from improper or sloppy test procedures the Regional Director or his representative will require the mix design be redone.

The Department will select the production asphalt cement content after reviewing the Marshall design data and any pavement performance experiences that may exist using similiar materials and gradation.

If all the specified Marshall mix criteria are met, the selected production asphalt cement content will generally be the submitted optimum asphalt cement content. In no case will the selected production asphalt cement content result in Marshall properties outside of the specified Marshall criteria limits.

VII. MONITORING PLANT MIX MARSHALL PROPERTIES AND PAVEMENT DENSITIES

The performance of bituminous concrete pavements is directly related to achieving good Marshall properties. The Marshall properties of most importance are: air voids, voids in the mineral aggregate, and % voids in the mineral aggregate filled with asphalt. The Marshall Mix Design requirements provide a rational method of simulating plant production to predict Marshall properties for the produced bituminous mixture.

To initially determine how well the Marshall design has predicted actual plant production, plant mix samples should be obtained and tested for Marshall properties. Also plant mix samples should be obtained to determine what effect normal plant production variations have on the bituminous mix properties.

Project evaluation should also be conducted to determine the Density and air void properties of the in place bituminous pavement. This is where it is essential to obtain acceptable Marshall properties in order that the pavement achieves its intended design life.

Evaluation of plant mix samples and pavement cores will maximize the use of the Regional Laboratory facilities and will provide useful information to aid the Materials Engineer in determining when either the mix design and/or construction procedures require corrections, in order to maintain pavements with good Marshall properties.

Plant monitoring and testing:

Closely monitor Hot Bins for shifts in gradation and analyze their effects on Marshall properties.

a. Using plant hot bin samples, prepare specimens at varying gradations produced to determine their effects on Marshall properties.

b. Obtain plant mix samples to evaluate expected variations in Marshall properties throughout normal production.

Project monitoring and testing:

Obtain representative project mix samples for Marshall density determination. Obtain pavement cores to determine percent Marshall density and pavement air voids. By obtaining project mix samples and pavement cores simultaneously, resultant possible density problems can be better analyzed as to whether it is due to the delivered mix and/or construction techniques.

Should the Region desire additional engineering information regarding this method, specific instructions will be issued by the Materials Bureau upon request.

APPENDIX 1

EQUIPMENT LIST

Marshall Design Laboratory
Equipment List & Specifications

All manufacturers & models of equipment mentioned subsequently are offered as examples which have been observed to conform consistently to the ASTM Standards applicable. Even if the recommended manufacturers and models of equipment are employed, each individual piece of equipment must be calibrated to the applicable ASTM Standard before use.

1. Specimen Mold Assembly conforming to ASTM D-1559. At least three are necessary. "MCM Mold Assembly" (Pine Instrument).

2. Specimen Extractor such as the "PX Specimen Extractor" (Pine Instrument).

3. Compaction Hammer conforming to ASTM D-1559 (Pine Instrument).

4. Compaction Pedestal conforming to ASTM D-1559 (Pine Instrument).

5. Specimen Mold Holder conforming to ASTM D-1559 (Pine Instrument).

6. An Automatic Compactor may be used. The "PMC 4 Compactor" (Pine Instrument) would take the place of #3, #4, and #5.

7. Breaking Head for testing Marshall samples conforming to ASTM D-1559. "PBH Breaking Head" (Pine Instrument) or equivalent.

8. Test Press conforming to ASTM D-1559. "PMT Tester" (Pine Instrument).

9. Flow Meter conforming to ASTM D-1559. "PFM Flow Meter" (Pine Instrument).

10. Suitable load measuring device conforming to ASTM D-1559.

11. Pine Instrument Recording Test Press model #850 may be used in place of #8, #9, and #10.

12. Constant Temperature Oven, the circulating air type is recommended. One is necessary, but two are preferred.

13. Mixing bowls of sufficient capacity with spoons for mixing samples. Stainless Steel bowls are recommended. Mechanical mixers are also acceptable, such as the type made by Hobart.

14. Constant Temperature Water Bath that has some type of circulation device. "PW 160" (Pine Instrument) or equivalent.

15. Scales: Aggregate batching, Bulk Specific Gravity Determination (ASTM-D2726), and Maximum Theoretical Specific Gravity Determination (ASTM-D2041) "Rice Method" shall use a scale or scales that have a minimum sensitivity and readability of a tenth gram. The scale or scales should have a minimum accuracy requirement of 0.1 grams, and a maximum requirement of 0.05% of test load or 1 gram, whichever is smaller.

15. Con't.

The Torsion Model IL-11, 4 1/2 kilogram capacity scale meets these requirements when in proper working order. This scale or equivalent is recommended for Marshall testing.

16. Apparatus for determining actual specific gravity of Marshall samples. A diagram of a suitable apparatus is on the following page. Equipment included in this apparatus consists of a scale with a capacity of at least 2 kg., meeting the requirements in #15 above, a five gallon pail that has a run-off to maintain constant water level for all weighing operations, and a stand to hold the scale in such a way as to allow weighing the samples in water.

17. Vacuum Pump for conducting Rice Specific Gravity Analysis (ASTM D-2041). This pump must have an accurate vacuum gauge conforming to ASTM D-2041.

18. Container for running Rice Test conforming to ASTM D-2041. Glass Mason Jars are acceptable. Jar capacity should be 2000 ml. (2 quart).

19. Thermometers for determining temperatures of heated aggregates, asphalt, and compaction temperature of samples. Thermometers must conform to ASTM D-1559. Precision thermometers (77°F, 140°F) (25°C, 60°C) are needed to determine water bath temperatures.

20. Sample trays for heating aggregate. Five trays are needed and each one must have at least a 1200 gram capacity.

21. Two Hot Plates are also needed. Plates must have some type of thermostat.

22. Steel Spoons are necessary for placing samples into molds.

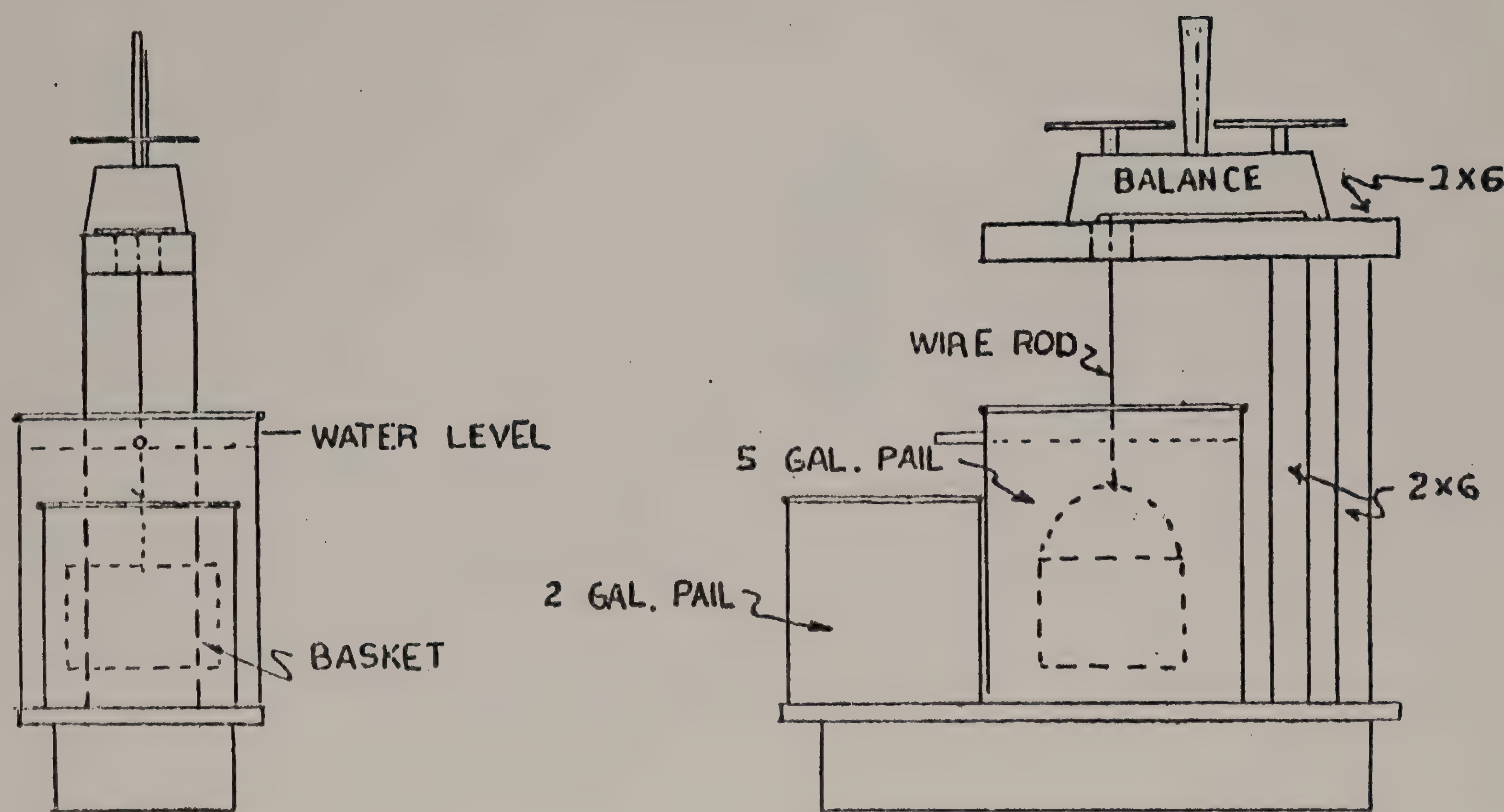
23. Other miscellaneous equipment can be found in ASTM D-1559.

24. Sieve Shaker (Tyler Manufacturing Company Rotap).

25. Fine Aggregate Splitter.

26. Coarse Aggregate Splitter.

APPARATUS FOR DETERMINING MARSHALL SP. GR.



SCALE $1\frac{1}{2}'' = 1'$

APPENDIX 2

COMPLETED MIX DESIGN
(TYPICAL BATCH PLANT)

BR 261-1 (2/78)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU
JOB MIX FORMULA
MARSHALL MIX DESIGN
Type 6F Top Course
(High Friction)

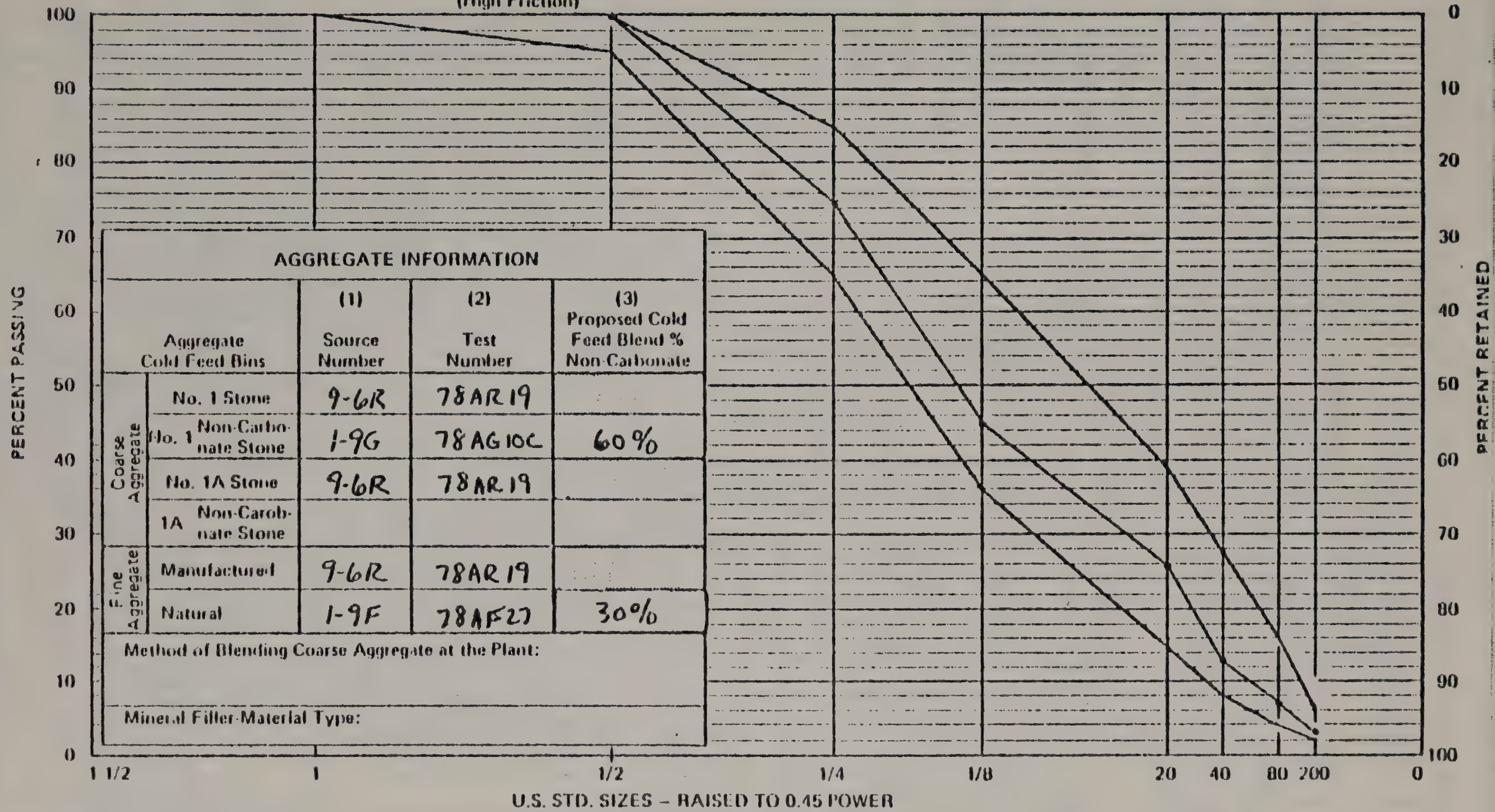
Region 11 Formula No. ____

Plant XYC BIT CORP. Pugmills 1

Plant Location SMITHTOWN

Submitted By J. BUSHEY Title ____

(Submission instructions on back)



AGGREGATE INFORMATION

	Aggregate Cold Feed Bins	(1) Source Number	(2) Test Number	(3) Proposed Cold Feed Blend % Non-Carbonate
Coarse Aggregate	No. 1 Stone	9-6R	78AR19	
	No. 1 Non-Carbonate Stone	1-9G	78AG10C	60%
	No. 1A Stone	9-6R	78AR19	
	1A Non-Carobnate Stone			
Fine Aggregate	Manufactured	9-6R	78AR19	
	Natural	1-9F	78AF27	30%

Method of Blending Coarse Aggregate at the Plant:

Mineral Filler-Material Type:

Sieve Size		2"	1 1/2"	1"	1/2"	1/4"	1/8"	No. 20	No. 40	No. 80	No. 200	Asphalt Content (Percent)	Asphalt Grade
% Passing	1. General Limits			100	95-100	65-85	30-65	15-39	8-27	4-16	2-6	5.8-7.0	
	2. JMF Range			100	95-100	68-82	38-53	19-33	8-20	4-11	2-5		AC ____
	3. Target Value			100	100	75	45	26	13	~~7~~8*	~~3~~4*	6.3	

Remarks *#80 AND #200 sieve values based on Extraction History

Recommended for Approval ____ Approved ____ Date ____

A 2-1

BR-88 (5/80)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION

MATERIALS BUREAU

MARSHALL GRADATION ANALYSIS WORKSHEET

TESTING AGENCY ABC TESTING INC.

TESTED BY J. BUSHEY ON 1/16/81

NO. OF HOT BINS AVERAGED 10

PLANT XYZ BIT. CORP.
SMITHTOWN, NY

REGION 11

ITEM 18403.1711

MIX TYPE 6F

AGGREGATE SOURCES

Course: #1 9-6R 40%
1-9G 60%
#1A 9-6R 100%

Fine: 9-6R 70%
9-9F 30%

Mineral Filler:
NONE

AVERAGE BIN BREAKDOWN

Sieve Sizes	BIN NO. 1 % retained	BIN NO. 1 % pass	BIN NO. 1A % retained	BIN NO. 1A % pass	BIN NO. FINE % retained	BIN NO. FINE % pass	MINERAL FILLER % retained	MINERAL FILLER % pass
1"	0	100.0						
1/2"	0.1	99.9		100.0				
1/4"	97.2	2.7	8.6	91.4		100.0		
1/8"	2.2	0.5	85.7	5.7	0.2	99.8		
20			5.2	0.5	39.4	60.4		
40					30.0	30.4		
80					14.8	15.6		
200					8.3	7.3		
PAN	0.5		0.5		7.3			
TOTALS	100.0		100.0		100.0			

COMBINED AVERAGE GRADATION

BIN	% BATCH	% Passing Sieve 1"	1/2"	1/4"	1/8"	20	40	80	200
1	22.3	22.3	22.3	0.6	0.1				
1A	35.1	35.1	35.1	32.1	2.0	0.2			
FINE	42.6	42.6	42.6	42.6	42.5	25.7	13.0	6.6	3.1
Min. Filler									
TOTAL	100.0	100.0	100.0	75.3	44.6	25.9	13.0	6.6	3.1
Spec. LIMITS			95/100	65/85	36/65	15/39	8/27	4/16	2/6

COMBINED MARSHALL GRADATION @ 5.0 % BITUMEN

BIN	% BATCH	GRAMS BATCH	WEIGHT RETAINED (GRAMS) 1"	1/2"	1/4"	1/8"	20	40	80	200	PAN	TOTAL Wgt. Ret.
1	22.3	254.2		0.3	247.0	5.6					1.3	254.2
1A	35.1	400.1			34.4	342.9	20.8				2.0	400.1
FINE	42.6	485.7				1.0	191.3	145.7	71.9	40.3	35.5	485.7
Min. Filler												
TOTAL	100.0	1140.0	1200.0 gr. X 5.0 % Bit. = 60 gr. A. C.									
			1200.0 gr. − 60 gr. A. C. = 1140 gr. Aggregate									

Remarks:

(over)

3R 79 (3/81)
COMPUTATION OF MARSHALL
MIX PROPERTIES

A2-3

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ITEM 18403.1711 REGION 11

MIX TYPE 6F

PRODUCER XYZ BIT. CORP. LOCATION SMITHTOWN

Specimen	Asphalt Content	Weight - Grams In Air	Weight - Grams In Water	Weight - Grams S.S.D.	Volume CC	Specific Gravity Bulk G_{mb}	Specific Gravity Theor. G_{mm}	Voids Total Mix	Unit Wt. Lb/Cu Ft	Stability-Lb Measured	Stability-Lb Corrected	Flow 1/100 Inch
a	b	c	d	e	f	g	h	i	j	k	l	m
					(e-d)	$\frac{c}{f}$		$100\frac{(h-g)}{h}$	(gX62.4)			
A	5.0	1163.6	663.6	1172.2	508.6	2.287				1530	1530	12
B	5.0	1168.0	665.4	1180.6	515.2	2.267				1320	1320	13
C	5.0	1162.0	663.3	1172.2	508.9	2.283				1480	1480	13
AVG.	5.0					2.279	2.445	6.79	142.2		1443	13
A	5.5	1160.5	664.8	1167.6	502.8	2.308				1640	1706	14
B	5.5	1161.1	670.8	1171.7	500.9	2.318				1670	1737	13
C	5.5	1246.3	723.3	1261.9	538.6	2.314				1780	1655	14
AVG.	5.5					2.313	2.421	4.67	144.3		1700	14
A	6.0	1189.6	683.6	1194.6	511.0	2.328				1790	1790	15
B	6.0	1168.4	667.9	1169.4	501.5	2.330				1750	1820	15
C	6.0	1121.2	644.1	1122.1	478.0	2.346				1710	1949	14
AVG.	6.0					2.335	2.405	2.91	145.7		1853	15
A	6.5	1155.9	665.0	1157.7	492.7	2.346				1760	1918	16
B	6.5	1128.1	648.7	1129.8	481.1	2.345				1620	1847	15
C	6.5	1144.9	657.6	1145.4	487.8	2.347				1800	1962	16
AVG.	6.5					2.346	2.379	1.39	146.4		1909	16
A	7.0	1103.0	634.1	1105.4	471.3	2.340				1550	1767	16
B	7.0	1124.7	645.7	1126.3	480.6	2.340				1560	1778	16
C	7.0	1129.8	647.9	1131.3	483.4	2.337				1550	1690	18
AVG.	7.0					2.339	2.360	0.89	146.0		1745	17

PREPARED BY J. BUSHEY ON 1/21/81

BR 77 (3/81)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ITEM 18403.1711 REGION 11

MIX TYPE 6F

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE
(Analysis by weight of total mixture)

PRODUCER XYZ BIT. CORP.

LOCATION SMITHTOWN, NY

COMPOSITION OF PAVING MIXTURE

CONSTITUENT MATERIAL		N.Y.S. D.O.T. Source Number	N.Y.S. D.O.T. Test Number	Specific Gravity, G Apparent	Specific Gravity, G Bulk		Mix Composition, % by weight of Total Mix, P — Mix or Trial Number 1	2	3	4	5
Course Aggregate	No. 1 Stone	9-6R	78AR19	2.707	2.635	P_1	8.5	8.4	8.4	8.3	8.3
	No. 1 Non-Carbonate Stone	1-9G	78AG10C	2.692	2.604	P_2	12.7	12.7	12.6	12.5	12.5
	No. 1A Stone	9-6R	78AR19	2.707	2.635	P_3	33.4	33.2	33.0	32.9	32.6
	1A Non-Carbonate Stone					P_4					
Fine Aggregate	Manufactured	9-6R	78AR19	2.707	2.635	P_5	20.2	20.1	20.0	19.9	19.8
	Natural	9-9F	78AF27	2.698	2.571	P_6	20.2	20.1	20.0	19.9	19.8
MINERAL FILLER						P_7					
TOTAL AGGREGATE						P_s	95.0	94.5	94.0	93.5	93.0
ASPHALT CEMENT @ 77 F (25C)				1.021		P_b	5.0	5.5	6.0	6.5	7.0

		EQUATIONS*	1	2	3	4	5
G_{mm}	Max. Sp. Gr. (G_{mm}) Paving Mix (ASTM D2041)		2.445	2.421	2.405	2.379	2.360
G_{mb}	Bulk Sp. Gr. (G_{mb}) compacted mix (ASTM D2726)	—	2.279	2.313	2.335	2.346	2.339
G_{sb}	Bulk Sp. Gr. (G_{sb}) total aggregate	(1)	2.617	2.617	2.617	2.617	2.617
G_{se}	Effective Sp. Gr. (G_{se}) total aggregate	(2)	2.639	2.631	2.633	2.621	2.618
G_{sa}	Apparent Sp. Gr. (G_{sa}) total aggregate	(1)	2.703	2.703	2.703	2.703	2.703
VMA	$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$	(3)	17.27	16.48	16.13	16.18	16.88
P_a	Air Voids (P_a) $= 100\left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right)$	(4)	6.79	4.46	2.91	1.39	0.89
P_{vma}	%VMA filled w/A.C. (P_{vma}) $= 100\left(\frac{VMA - P_a}{VMA}\right)$	(5)	60.68	72.94	81.96	91.41	94.73
P_{be}	Effective Asphalt Content (P_{be}) $= \frac{G_b(VMA - P_a)}{G_{mb}}$	(6)	4.70	5.31	5.78	6.44	6.98
	Stability [Marshall]	—	1443	1700	1853	1909	1745
	Flow [Marshall]	—	13	14	15	16	17

*EQUATIONS FROM CHAPTER V, SECTION E, NY MATERIALS METHOD 5.13

Prepared By J. BUSHEY on 1/21/81

BR-78. (3/81)

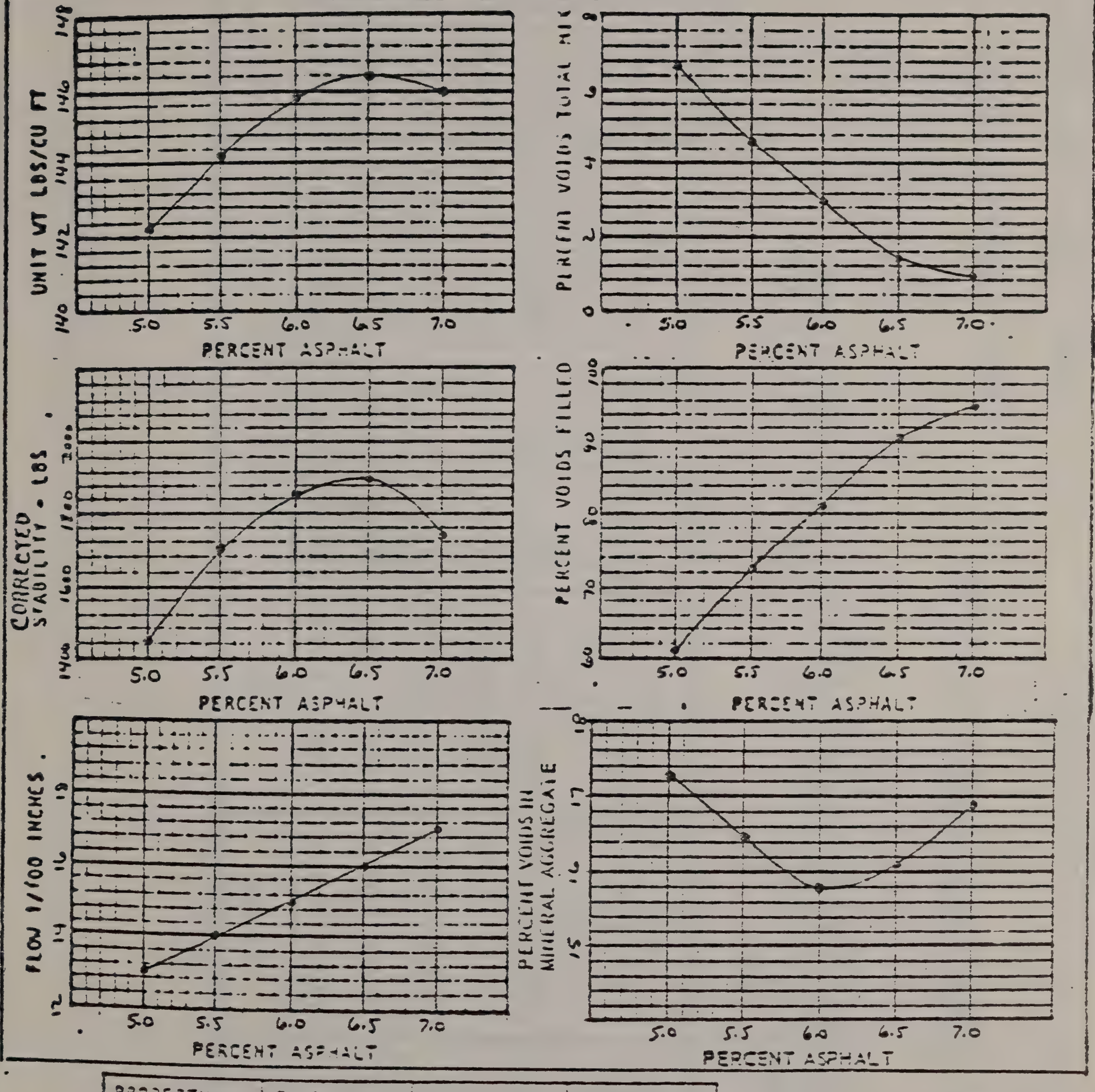
NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

REGION 11

MIX TYPE 6F

Producer XYZ BIT. CORP. Location SMITHTOWN, NY

MARSHALL TEST PROPERTY CURVES



PROPERTY	STABILITY	UNIT WT.	AIR VOIDS
PT. ON CURVE	PEAK	PEAK	@ 3.0%
% ASPHALT	6.5	6.5	6.0

TEST BY J. BUSHEY

DATE 1/21/81

VALUES AT OPTIMUM 6.3

PROPERTY	STABILITY	UNIT WT	AIR VOIDS	FLOW	VMA	VOIDS FILLED
SPEC.	1500 MIN *	N/A	2.0-4.0%	8-18	N/A	N/A
ACTUAL	1900	146.3	2.0	15	15.9	88

* 1200 [illegible]

A2-5

BR 70 (3/81)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

MIX TYPE 1A REGION 11

PRODUCER XYZ BIT. CORP.

LOCATION SMITHTOWN, NY

MAXIMUM SPECIFIC GRAVITY OF BITUMINOUS PAVING MIXTURES
ASTM D-2041 (RICE METHOD)

A= Weight of dry sample in air (grams)
D= Weight of flask filled with airless water at 77°F (25°C) grams
E= Weight of flask filled with water and sample at 77°F (25°C) grams

$$MTSG = \frac{A}{A+D-E}$$

ASPHALT CONTENT	5.0 %		5.5 %		6.0 %		6.5 %		7.0 %	
TEST NO.	1	2	1	2	1	2	1	2	1	2
A	1188.4	1179.4	1194.2	1190.6	1182.4	1187.6	1184.6	1190.3	1178.8	1183.5
D	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6	2659.6
E	3361.3	3357.2	3360.3	3358.6	3350.4	3353.4	3345.4	3350.4	3338.7	3341.8
A + D - E	486.7	481.8	493.5	491.6	491.6	493.8	498.8	499.5	499.7	501.3
MTSG	2.442	2.448	2.420	2.422	2.405	2.405	2.375	2.383	2.359	2.361
Average MTSG	2.445		2.421		2.405		2.379		2.360	

Test By J. BUSHEY on 1/21/81

A 2-6

APPENDIX 3

STABILITY CORRELATION TABLE

STABILITY CORRELATION RATIOS[a]

Volume of Specimen, cm^3	Correlation Ratio
406 to 420	1.47
421 to 431	1.39
432 to 443	1.32
444 to 456	1.25
457 to 470	1.19
471 to 482	1.14
483 to 495	1.09
496 to 508	1.04
509 to 522	1.00
523 to 535	0.96
536 to 546	0.93
547 to 559	0.89
560 to 573	0.86
574 to 585	0.83
586 to 598	0.81
599 to 610	0.78
611 to 625	0.76

[a] The measured stability of a specimen multiplied by the ratio for the volume of the specimen equals the corrected stability for a 2 1/2 inch thick by 4 inch diameter specimen.

APPENDIX 4

ABBREVIATIONS

MARSHALL TEST DATA ABBREVIATIONS

G_{mb} = bulk specific gravity of compacted bituminous mixture

G_{mm} = maximum theoretical specific gravity of bituminous mixture

Pa = air voids in compacted bituminous mixture, % of total mix volume

VMA = voids in mineral aggregate

P_{vma} = % voids in the mineral aggregate filled with effective asphalt cement

P_{be} = effective asphalt cement content, % total weight of bituminous mixture

G_{sb} = aggregate bulk specific gravity

G_{se} = aggregate effective specific gravity

G_{sa} = aggregate apparent specific gravity

G_b = asphalt cement specific gravity at 77 F (25 C)

P = % total bituminous mixture by weight = 100%

P_b = % asphalt cement in bituminous mixture, by weight of total mixture

P_s = % total aggregate in bituminous mixture, by weight of total mixture

P_1, P_2, P_n = % aggregate mix composition, by weight of total mixture